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Mechanisms of Funding for Universal Service Obligations: the Electricity Case

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Abstract

The transition towards a more competitive regime in network industries (and specially in electricity sector) raises the relevant question of funding for the Universal Service Obligations (USOs). Our paper focuses on two ways of funding for universal service and equal treatment obligations ("Ubiquity and Non Discrimination constraints "): the funding through access charge (CS regime) or taxation (T regime). Using a network model including competition between an historical monopoly (in charge for the USOs) and an entrant, we obtain some results concerning gains and losses of social welfare due to those mechanisms. We show that most of the time it is socially better to let the historical monopoly be active whatever the type of funding for USOs applying, and whatever profitability of the firms is. However, when the entrant is active, we can highlight that the introduction of the T regime (compared to the CS one) implies either welfare deterioration or an entry prevention strategy by the historical firm. Therefore, the T regime could not be an argument for the regulator to promote vertical separation of the historical firm (according to the European community line).

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1 Introduction

The process of deregulation in network industries (telecommunications, electricity, gas, transportation, etc...) raises some questions about the new types of regulation, pricing mechanisms, market structures, etc... In these network utilities, the regulator imposes Universal Service Obligations (USOs) to fulfil some equity principles; on previous regulated markets, monopolies were in charge of these USOs. The transition towards a more competitive regime, arises the relevant question of allocating and funding for these USOs.

In this general framework, our paper focuses on the deregulation process in electricity market and particularly, on the funding for USOs imposed in this sector. As defined in Cremer *et alii* (2001), *"Universal service in this sector consists of the obligation of electric utilities to supply service in a continuous manner, to meet the needs of all customers requesting it, and provide it at the minimum possible price".* More precisely, in many European countries, the Universal Service Obligations in the electricity market are based on two principles:

- the Ubiquity constraint that underlines the obligation to supply customers located in a given area, specially non profitable customers;
- the Non Discrimination constraint that imposes the equal treatment of the customers concerned (for instance, spatial equalization of tariffs).

These obligations are clearly stipulated in the European Directive concerning Common Rules for the internal market in electricity[1]: "*Member States may impose on distribution companies an obligation to supply customers located in a given area. The tariff for such supplies may be regulated, for instance to insure equal treatment of the customers concerned*" .

These Universal Service Obligations could be more precisely defined (Chone *et alii,* 1999, 2000, 2002): " *The ubiquity constraint states that all consumers should be connected to a network, whatever their location. The non discrimination constraint states that the same tariff should be proposed to all those consumers, whatever their location or their connection cost*" .

[1]Article 10 of the Directive 96/92/EC of the European Parliament and of the Council of 19 December 1996 (Chapter V concerning distribution system operation).

The aim of our paper is to point out mechanisms of funding for " ubiquity and non discrimination constraints (UND)" : what are the available mechanisms of funding for the obligation to serve some customers with high connection costs in spread rural areas (ubiquity constraint) without tariffs discrimination (non discrimination constraint)?

Firstly, the USO could be financed only by the operator who faces the USO (the historical firm). In that case, the funding is made with direct cross-subsidies between rural and urban customers. As is underlined in Cremer *et alii* (2001), *"competition may limit the ability of the operator to finance the USO through cross-subsidies. The surcharges levied on some consumer groups may open the door to cream skimming (by possibly less efficient competitors) which creates additional distortions and may threaten the viability of the operator".* For that reason and for equity concerns, all regulatory agencies consider the direct cross-subsidization mechanism as nonviable for emerging competitive markets.

Secondly, the USO could be financed by all operators on the electricity market. In that case, two main instruments could be used:

- First, UND charges could be integrated in the amount of access charge paid by all suppliers, necessarily involving indirect cross-subsidies.;
- Second, UND constraints could be financed by means of a fund responsible for the recovering of the charges induced by UND constraints (all suppliers could finance the fund with the payment of a tax in proportion to the volume of electricity supplied).

These two regimes will be discussed in our paper in the framework of standard network models with essential facilities (transport infrastructures)[2]. Initiated by the economic analysis of David and Mirabel (2000) about regulation and pricing mechanisms in the context of third party access to a gas network, the structure of our model is similar: two firms (an incumbent firm and an entrant firm) compete for the electricity market; the incumbent is responsible for operating the transmission system and is responsible for UND constraints; the entrant firm has to pay for the access to transport network in order to serve the electricity market. Motivated by the paper of Chone *et al.* (2002), our model integrates two types of customers with respect to their connection costs[3] in order to analyze UND constraints in the electricity sector.

[2]See for example Armstrong, Doyle and Vickers (1996).

[3]The type of a user corresponds to its spatial location with different connection costs between high density areas (urban area) and low density areas (rural areas).

In that case, the outline of the paper is as follows. In section 2, we draw the structure and notations of the model. We investigate the mechanisms of funding for USOs in following sections (funding through access pricing in section 3 and funding through a fund in section 4) and we compare the equilibria of the corresponding games in terms of social welfare (section 5). Section 7 contains some concluding comments concerning potential extensions of our model and specially, the possibilities of allocation for USOs (for instance, by means of an auction process) to extend the " restricted entry" scenario.

2 The model

2.1 The framework

2.1.1 Structure of the electricity market

As in the working paper of Chone P. *et al.* (2002), there are two types of electricity consumers denoted by $\mu \in \{\overline{\mu}, \underline{\mu}\}$. The type of user corresponds to its cost of connection to the network: the value $\mu = \overline{\mu}$ (resp. $\mu = \underline{\mu}$) denotes a user with a high (resp. low) cost of connection corresponding to a user's location in low (resp. high) density area. The proportion of consumers of type $\overline{\mu}$ is $\overline{\alpha}$ and that of consumers is $\underline{\alpha}$ ($\overline{\alpha}+\underline{\alpha} = 1$). A consumer who buys q Kwh of electricity receives a net monetary surplus $u(q) = w(q) - T(q)$ where $w(q)$ is supposed to be increasing and concave and $T(q)$ represents the tariff charged by a consumer. As it is pointed out in the paper of Chone P. *et al.* (2002), the demand addressed to firm K by a consumer facing the tariff $T(q)$ is given by the equilibrium relation $w'(q) = T'(q)$.

On the electricity market supply side, there are two firms $K = I, E$; I is the historical public monopoly (the " incumbent " in the literature) which supplies electricity and which is responsible for the transport of electricity on its network. We suppose that another firm, the entrant (E), competes for the electricity market (only for consumers of type $\mu = \underline{\mu}$). Concerning Universal Service Obligations, the incumbent has to serve the consumers of type $\mu = \overline{\mu}$ (high costs of transport). Finally, the entrant uses the incumbent network to supply electricity on the downstream market (Third Party Access system) and pays an access charge for this transport service. Figure 1 illustrates the structure of the electricity market under ubiquity constraints.

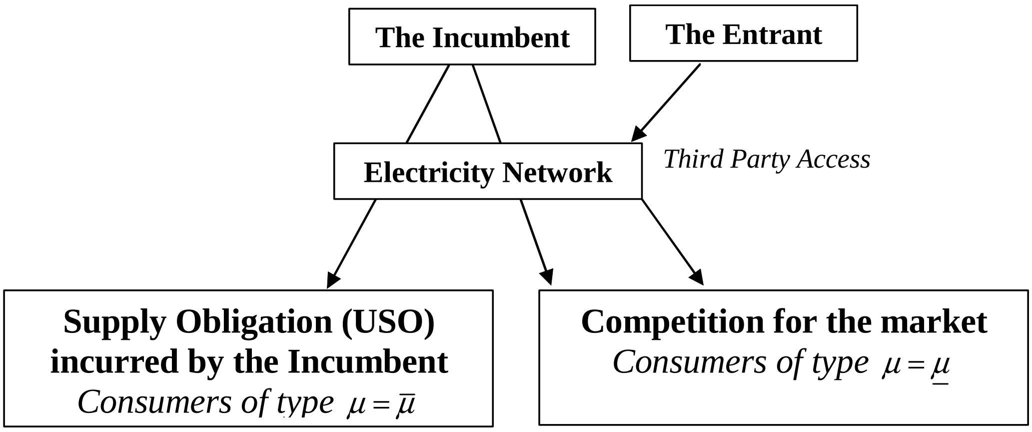

Figure 1: Structure of the electricity market

2.1.2 The costs incurred by the incumbent and the entrant

The cost incurred by the incumbent depends directly on the type of consumers (different connection costs). On the contrary, the cost incurred by the entrant is not directly linked to the type of consumers (it is indirectly dependent on the type of consumers by way of the access charge). In that way, as it includes essential facilities features in the model, our analysis can be considered as an extension of Chone *et alii* (2002).

The supply cost when providing q Kwh for the entrant (for all the types of consumers) is then:

$$C_E(q, \mu) = (k + a)q \tag{1}$$

where k is the unit cost of electricity production and a is the access charge paid for the transport service.

The cost of distribution for the incumbent when providing q Kwh depends on the transport cost $c_t(q, \mu)$ and writes:

$$C_I(q, \mu) = kq + c_t(q, \mu) \tag{2}$$

There are two main assumptions made on the features of the transport cost function:

- As pointed out in introduction of the paper, the connection costs depends on the type of consumers with the following assumption:

$$c_t(q, \overline{\overline{\mu}}) > c_t(q, \underline{\mu}), \ \forall q > 0 \tag{3}$$

- We assume that the transport network generates increasing returns to scale ; this assumption is obvious since the transport infrastructure induces high fixed costs. In that case we can write:

$$\forall \mu, \frac{c_t(q,\mu)}{q} > \frac{\partial c_t(q,\mu)}{\partial q} \tag{4}$$

From now, we use the following specification of the transport cost function to obtain a more tractable model:

$$c_t(q,\mu) = cq + F(\mu) \text{ with } F(\underline{\mu}) < F(\overline{\mu}) \tag{5}$$

This assumption is relevant in the electricity market where marginal costs of transport are relatively constant with the level of quantity transmitted.

2.1.3 Third Party Access to the Network and corporate profits

As pointed out, the entrant pays an access charge for the transport of electricity on the incumbent network. We assume that the incumbent has also to pay this access charge which represents a cost for its activity of supply and a revenue for its activity of transport. In that case, the access charge induces no effects on the level of incumbent global profit (profit stemming from distribution and transport activities). This neutral monetary transfer ($a \times q$) from distribution activity to transport activity of the incumbent is integrated in our model for an objective of transparency of the incumbent accounts. This assumption, concerning unbundling and transparency of accounts, is based on regulatory practices in many industrial countries[4].

In that case, we can write the "accounting profit" derived from the transport activity for the incumbent when q Kwh are transmitted through the electricity network to a consumer of type μ :

$$\pi_t(q,\mu) = aq - c_t(q,\mu) \tag{6}$$

The entrant's profit when providing one consumer of type μ with q Kwh writes:

$$\pi_E(q,\mu) = T_E(q,\mu) - C_E(q,\mu) \tag{7}$$

The incumbent's aggregate profit is the sum of the profit resulting from distribution activity $\pi_I(q,\mu) = T_I(q,\mu) - (k+a)q$ and the profit derived from the transport activity (see relation 6):

$$\widehat{\pi}_I(q,\mu) \equiv \pi_I(q,\mu) + \pi_t(q,\mu) = T_I(q,\mu) - (k+a)q + \pi_t(q,\mu) = T_I(q,\mu) - C_I(q,\mu) \tag{8}$$

[4]In the European Directive concerning Common Rules for the internal market in electricity (Chapter IV), it is written: "*Integrated electricity undertakings shall, in their internal accounting, keep separate accounts for their generation, transmission and distribution activities (?) with a view to avoiding discrimination, cross-subsidization and distortion of competition. They shall include a balance sheet and a profit and loss account for each activity in notes to their accounts*".

We define S_K the surplus derived from the relationship between a consumer of type μ and the firm K which provides q Kwh :

$$S_K(q,\mu) = u(q) + \pi_K(q,\mu) + \pi_t(q,\mu) \tag{9}$$

Using the expressions of incumbent and entrant profits, this surplus function does not depend finally on K:

$$S_K(q,\mu) = w(q) - kq - c_t(q,\mu) \equiv S(q,\mu) \tag{10}$$

2.2 The benchmark case: no Universal Service Obligations

Two main assumptions underlie the construction of our model and will influence strongly our results:

- the unbundling and transparency of accounts require an accounting separation of vertically integrated activities. In that case, we suppose that the regulation of the access charge allows the balance of the accounts for the incumbent transport activity. In other words, the access charge regulation is a standard "cost of service regulation", that is to say, the level of access charge is equal to the average cost of transport[5]:

$$\pi_t(q,\mu) = 0 \Rightarrow a = \frac{c_t(q,\mu)}{q} = c + \frac{F(\mu)}{q}$$

- In the first best (FB) situation (where the surplus is maximum), with a cost of service regulation, we can write:

$$\frac{\partial S(q,\mu)}{\partial q} = 0 \Leftrightarrow \frac{\partial u(q)}{\partial q} + \frac{\partial \pi_K(q,\mu)}{\partial q} = 0 \tag{11}$$

  So

$$q_\mu^{FB} \text{ verifies } w'(q_\mu^{FB}) = k + c \tag{12}$$

  Because of relation (5), first best production level is independent of the consumer type; so we will henceforth write $q_\mu^{FB} = q^{FB}$.

In this first best situation, we assume that:

$$S(q^{FB},\underline{\mu}) > 0 > S(q^{FB},\overline{\mu}) \tag{13}$$

[5]Note that this level of the access charge (a = Average Cost) allows the government to maximize the collective surplus under budget-balanced constraint for transport activity (see appendix A).

This main assumption means that high cost consumers are not profitable and would not be served by any firm without universal service obligations.

In the benchmark case, we assume that no firm will serve the non profitable consumers of type $\mu = \overline{\mu}$ (there is no Universal Service Obligation). The competitive game between the incumbent and the entrant is a sequential game in which firm I is the leader. This representation is relevant in the case of a market where a (dominant) incumbent faces a new entrant. It is supposed that the strategies of the firms are represented by the utility level offered to electricity consumers[6]. As pointed out by Chone *et alii.* (2002), each firm reacts to the strategy of its rival by choosing the share of the surplus it leaves to the consumer.

When he provides electricity to consumers of type $\mu = \underline{\mu}$, the incumbent, chooses a level of production q corresponding to the first best situation. Indeed, the quantity supplied by the incumbent is defined by[7]:

$$\begin{aligned} q_{\underline{\mu}}^{I} &= \arg\max_{q\geq 0} \left\{\Pi_I(q) = \underline{\alpha}\,\hat{\pi}_I(q)\right\} \\ &\Leftrightarrow \frac{\partial \Pi_I(q)}{\partial q} = 0 \\ &\Leftrightarrow \underline{\alpha}\left(T'\left(q_{\underline{\mu}}^{I}\right) - k - c\right) = 0 \\ &\Leftrightarrow w'\left(q_{\underline{\mu}}^{I}\right) = k + c \end{aligned} \tag{14}$$

The direct comparison of this expression and (12) yields: $q_{\underline{\mu}}^{I} = q^{FB}$.

On the contrary, when he provides electricity to consumers of type $\mu = \underline{\mu}$, the entrant chooses a level of production $q_{\underline{\mu}}^{E} \neq q^{FB}$; the entrant quantity supplied is defined by:

$$\begin{aligned} q_{\underline{\mu}}^{E} &= \arg\max_{q\geq 0} \left\{\Pi_E(q) = \underline{\alpha}\pi_E(q)\right\} \\ &\Leftrightarrow \frac{\partial \Pi_E(q)}{\partial q} = 0 \\ &\Leftrightarrow \underline{\alpha}\left(T'\left(q_{\underline{\mu}}^{E}\right) - k - a\right) = 0 \\ &\Leftrightarrow w'\left(q_{\underline{\mu}}^{E}\right) = k + a \end{aligned} \tag{15}$$

Under cost of service regulation, the expression (15) yields:

$$w'(q_{\underline{\mu}}^{E}) = k + c + \frac{F(\mu)}{q_{\underline{\mu}}^{E}}$$

[6] It is equivalent to work with tariff or quantity variables.

[7] Note that the incumbent is submitted to an accounting unbundling so that it determines the level of electricity supply which maximizes the aggregate profit (derived from transport and distribution activities); in other words, the incumbent remains vertically integrated.

Under the assumption of increasing returns to scale for the transport activity ($AC_t \geq MC_t$), and comparing the expressions (12) and (15), we can write:

$$w'(q^E_{\underline{\mu}}) > w'(q^{FB}) \Rightarrow q^E_{\underline{\mu}} < q^{FB} \tag{16}$$

In that case, the surplus derived from the relationship between a consumer of type $\mu = \underline{\mu}$ and firm K is higher when the incumbent is active:

$$S(q^{FB}) > S(q^E_{\underline{\mu}}) > 0 \tag{17}$$

This situation corresponds to a particular case of Chone *et alii* (2002); so we can expect that their lemma 1 will apply: the incumbent is the only firm active.

The outcome of the competitive game leads to surplus sharing between the firm K which is active and the consumers of type $\mu = \underline{\mu}$; the surplus to be shared is equal to $S = \underline{u}_K + \pi_K + \pi_{t\ |\pi_t=0}$ where $\underline{u}_K$ represents the level of utility proposed by the firm K to a consumer of type $\mu = \underline{\mu}$.

First, it is necessary to compute the best reply function of firm E in response to the strategy $\underline{u}_I$ of the firm I. Each firm reacts to the strategy of its rival by choosing the share of the surplus (S) it offers to the consumer. Facing $\underline{u}_I$, firm E can offer $\underline{u}_I + \varepsilon$ to the consumer if $\pi_E = S(q^E_{\underline{\mu}}) - \underline{u}_I - \varepsilon \geq 0$, that is to say if $S(q^E_{\underline{\mu}}) \geq \underline{u}_I + \varepsilon$ then $S(q^E_{\underline{\mu}}) > \underline{u}_I$. In that case, firm E is active and serves the consumers of type $\mu = \underline{\mu}$. On the contrary, if $S(q^E_{\underline{\mu}}) < \underline{u}_I$, the firm E has no incentive to be active. The best reply function of firm E in response to the strategy $\underline{u}_I$ of the firm I then writes:

$$\underline{u}_E(\underline{u}_I) = \begin{cases} \underline{u}_I & \text{if } \underline{u}_I < S(q^E_{\underline{\mu}}) \\ u \in [0, \underline{u}_I[& \text{if } \underline{u}_I > S(q^E_{\underline{\mu}}) \end{cases} \tag{18}$$

In that case, the strategy of the incumbent (the leader) consists in reducing the profit of the entrant to zero, that is to say, $\underline{u}_I = S(q^E_{\underline{\mu}})$. Therefore, the incumbent serves consumers of type $\mu = \underline{\mu}$ and its profit writes:

$$\hat{\pi}_I = S(q^{FB}) - S(q^E_{\underline{\mu}}) \geq 0 \tag{19}$$

3 "Cross-Subsidies Mechanism" (CS Regime): funding for USOs through the access charge

In this regime, we assume that Ubiquity and Non Discrimination (UND) constraints have to be taken into account only by the incumbent. That is to say, we do not focus on USO allocation[8]. In other words, the historical firm must serve consumers of type $\overline{\mu}$ (Ubiquity constraint); at the same time, the level of utility offered by the incumbent must be the same for the two types of consumers (Non Discrimination constraint) so that:

$$\underline{u}_I = \bar{u}_I \equiv u \geq 0 \tag{20}$$

We assume that the entrant is not authorized to supply electricity to non-profitable consumers (Restricted Entry Regime); in this situation, the entrant and the incumbent compete only for the consumers of type $\mu = \underline{\mu}$. In the case of the funding for USOs through the access charge, we assume that the regulation of the access tariff[9] allows the monopoly to balance the profit derived from its transport activity[10], so a is such that :

$$\begin{aligned} \Pi_t &= \underline{\alpha}\pi_t(q, \underline{\mu}) + \overline{\alpha}\pi_t(q, \overline{\mu}) = 0 \\ &\Leftrightarrow a(\overline{\alpha}q^I_{\overline{\mu}} + \underline{\alpha}q^K_{\underline{\mu}}) = \underline{\alpha}c_t(q^K_{\underline{\mu}}, \underline{\mu}) + \overline{\alpha}c_t(q^I_{\overline{\mu}}, \overline{\mu}) \\ &\Leftrightarrow \widetilde{a} = \frac{c_t(\widetilde{q}^K_{\underline{\mu}}, \underline{\mu}) + \overline{\alpha}c_t(\widetilde{q}^I_{\overline{\mu}}, \overline{\mu})}{(\widetilde{q}^K_{\underline{\mu}} + \overline{\alpha}\widetilde{q}^I_{\overline{\mu}})} = c + \frac{F(\overline{\mu}) + \eta F(\underline{\mu})}{\widetilde{q}^I_{\overline{\mu}} + \eta\widetilde{q}^K_{\underline{\mu}}} \end{aligned} \tag{21}$$

with $\eta = \underline{\alpha}/\overline{\alpha}$.

Note that variables with tilda symbol ($\sim$) corresponds to this CS regime.

As pointed out in the benchmark regime, when he provides electricity to consumers of types $\mu = \underline{\mu}$ or $\mu = \overline{\mu}$, the incumbent chooses a level of production corresponding to the first best level (verifying 14), that is to say: $\widetilde{q}^I_{\underline{\mu}} = q^{FB}$ and $\widetilde{q}^I_{\overline{\mu}} = q^{FB}$. Using the expression of the access charge given by (21), the level of production supplied by the entrant is defined with (15), that is $w'(\widetilde{q}^E_{\underline{\mu}}) = k + \tilde{a}$.

As stipulated in the benchmark scenario, we compute first the best reply function of firm E in response to strategy $\underline{u}_I$ of firm I. Each firm reacts to the strategy of its rival by choosing

[8] For this topic, see Choné *et al.* (2002) and Hoernig (2001).

[9] Other regulation rules could be integrated in the analysis, specially normative one (maximization of welfare). Here and so far, we take exogenous regulation rules for two reasons: 1) we use the European Directive for Electricity market recommendations as assumptions 2) we focus only on firms strategies.

[10] This seemingly ad-hoc assumption stems from increasing return to scale in transport activity. As it is stipulated in footnote 5, this rule is also a second best.

the share of the surplus (S) it offers to the consumer. Facing $\underline{u}_I$, firm E can offer $\underline{u}_I + \varepsilon$ to the consumer if $S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - u - \varepsilon \geq 0$, that is to say if $S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) \geq u + \varepsilon$. In that case, firm E is active and serves consumers of type $\mu = \underline{\mu}$. On the contrary, if $S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) < u$, firm E has no incentive to be active. The best reply function of firm E in response to the strategy u of firm I then writes:

$$\underline{u}_E(u) = \begin{cases} u & \text{if } u < S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) \\ \upsilon, \ \forall \upsilon \in \left[0, S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu})\right[& \text{if } u \geq S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) \end{cases} \tag{22}$$

It is necessary to compute the profit of the incumbent (the leader of the sequential game) in order to point out its strategy.

3.1 The incumbent's profit

3.1.1 The incumbent serves the two types of consumers

Taking into account the E best reply, the incumbent serves consumers of type $\mu = \underline{\mu}$ if $u \geq S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu})$; in that case, its total profit is:

$$\begin{aligned} \hat{\Pi}^I_I &= \underline{\alpha}\widehat{\pi}_I(q^{FB}, \underline{\mu}) + \overline{\alpha}\widehat{\pi}_I(q^{FB}, \overline{\mu}) = \underline{\alpha}\left(S(q^{FB}, \underline{\mu}) - u\right) + \overline{\alpha}\left(S(q^{FB}, \overline{\mu}) - u\right) \\ &\Leftrightarrow \ \hat{\Pi}^I_I = \underline{\alpha}S(q^{FB}, \underline{\mu}) + \overline{\alpha}S(q^{FB}, \overline{\mu}) - u \equiv \widetilde{W}_{II} - u \end{aligned} \tag{23}$$

where $\widetilde{W}_{II}$ is social welfare of this CS regime when I serves the profitable consumers. Note that it is also the first best level of social welfare. It is easy to see that the incumbent (surplus sharing) strategy consists in offering to the consumers the minimum level of utility that allows him to be active:

$$\begin{aligned} \widetilde{u} &\in \underset{u \geq S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu})}{\arg\max} \ \widehat{\Pi}^I_I \\ &\Leftrightarrow \ u = \widetilde{u}_{II} = S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) \end{aligned}$$

3.1.2 The entrant serves the profitable consumers

The entrant serves consumers of type $\mu = \underline{\mu}$ if $S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) > u$; in that case, the total profit for the incumbent is:

$$\begin{aligned} \widehat{\Pi}^E_I &= \underline{\alpha}\pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) + \overline{\alpha}\widehat{\pi}_I(q^{FB}, \overline{\mu}) \\ &= \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) + \overline{\alpha}\left(S(q^{FB}, \overline{\mu}) - u\right) + \underline{\alpha}S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \underline{\alpha}S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) \\ &\Leftrightarrow \ \widehat{\Pi}^E_I = \widetilde{W}_{IE} - u - \left\{S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - u\right\} \end{aligned}$$

where $\widetilde{W}_{IE}$ is social welfare of this CS regime when E serves the profitable consumers, that is:

$$\widetilde{W}_{IE} = \underline{\alpha} S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) + \overline{\alpha} S(q^{FB}, \overline{\mu})$$

This profit is maximized for $u = 0$; in that case, using (22), the level of utility offered to the consumers is $\underline{u}_E(u) = \bar{u}_I = \tilde{u}_{IE} = 0$, and optimal incumbent profit becomes:

$$\widehat{\Pi}^E_I = \widetilde{W}_{IE} - \underline{\alpha} \left\{ S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) \right\} \tag{24}$$

Remark 1 *The regime where the incumbent serves the consumers of type* $\mu = \underline{\mu}$ *is always profitable from a collective point of view:* $\widetilde{W}_{IE} < \widetilde{W}_{II}$

3.2 Incumbent's strategy

We compare the two levels of the incumbent's profit in order to point out the strategy chosen by the leader:

$$\begin{aligned} \Delta\widehat{\Pi} &= \widehat{\Pi}^I_I - \widehat{\Pi}^E_I = \left\{ \widetilde{W}_{II} - \tilde{u}_{II} \right\} - \left\{ \widetilde{W}_{IE} - \underline{\alpha} \left[S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) \right] \right\} \\ &\Leftrightarrow \Delta\widehat{\Pi} = \widetilde{W}_{II} - \widetilde{W}_{IE} - \overline{\alpha} \left\{ S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) \right\} \end{aligned} \tag{25}$$

In that case:

$$\Delta\widehat{\Pi} \gtreqless 0 \Leftrightarrow \widetilde{W}_{II} \gtreqless \widetilde{W}_{IE} + \overline{\alpha} \left\{ S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) \right\}$$

Lemma 1 *If social welfare* $\widetilde{W}_{II}$ *is relatively higher (resp. lower) than* $\widetilde{W}_{IE}$ *, then it is profitable (resp. not profitable) for the incumbent to serve the consumers of type* $\mu = \underline{\mu}$*; in that case, the entrant is inactive (resp. active).*

In order to give an other interpretation of lemma 1, we can transform expression (25) corresponding to the difference in the incumbent's profits:

$$\begin{aligned} \Delta\widehat{\Pi} &= \left\{ \widetilde{W}_{II} - \tilde{u}_{II} \right\} - \left\{ \underline{\alpha} \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) + \overline{\alpha} \left(S(q^{FB}, \overline{\mu}) - \tilde{u}_{IE} \right) \right\} \\ &\Leftrightarrow \Delta\widehat{\Pi} = \underline{\alpha} S(q^{FB}, \underline{\mu}) + \overline{\alpha} S(q^{FB}, \overline{\mu}) - S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) + \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \underline{\alpha} \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \overline{\alpha} S(q^{FB}, \overline{\mu}) \\ &\Leftrightarrow \Delta\widehat{\Pi} = \underline{\alpha} \left\{ S(q^{FB}, \underline{\mu}) - S(\widetilde{q}^E, \underline{\mu}) \right\} + \overline{\alpha} \left\{ \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) \right\} \end{aligned}$$

This leads to the new inequalities:

$$\Delta\widehat{\Pi} \gtreqless 0 \Leftrightarrow \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) \gtreqless S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \eta \left\{ S(q^{FB}, \underline{\mu}) - S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) \right\}$$

Corollary 1 *If the incumbent profit derived from the transport activity for profitable consumers, $\pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu})$, is relatively high (resp. low), then the incumbent (resp. the entrant) serves the profitable consumers.*

In the case where the incumbent profit derived from the transport activity for profitable consumers $\pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu})$ is high, the entrant is inactive (the entrance is not profitable due to the high level of access charge). The activity of transport for consumers of type $\mu = \underline{\mu}$ subsidizes the incumbent 's activity for non-profitable consumers. In that case, the utility proposed to all consumers is higher $\left(\tilde{u}_{II} = S(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}}, \underline{\mu})\right) > (\tilde{u}_{IE} = 0)$.

4 Funding for USOs through Taxation and Lump Sum Transfers (T regime)

In this regime, we assume that the regulation of the access tariff doesn't allow the incumbent to balance the profit derived from its transport activity (for the two types of consumers). With an objective of allocative equity, the regulated access tariff allows the network operator to balance the profit derived from the transport of electricity only for profitable consumers (as in the benchmark case without Universal Service Obligations):

$$\begin{aligned} \pi_t(\breve{q}^K_{\underline{\mu}}, \underline{\mu}) &= 0 \\ \Leftrightarrow \breve{a} &= \frac{c_t(\breve{q}^K_{\underline{\mu}}, \underline{\mu})}{\breve{q}^K_{\underline{\mu}}} = c + \frac{F(\underline{\mu})}{\breve{q}^K_{\underline{\mu}}} \end{aligned} \tag{26}$$

Note that variables with the "short" symbol ($\smile$) correspond to this T regime.
Among others, this access rule is in particular derived from stylized facts of the European regulation of the electricity market: without USO (profitable market), no profit can be earned from transport activity. Because of increasing returns to scale, we suppose that this latter constraint is binding.

The USOs are funded through lump sum transfers which allow the network operator to balance the profit derived from the transport of electricity for non profitable consumers:

$$\pi_t(\breve{q}^I_{\overline{\mu}}, \overline{\mu}) + \frac{1}{\overline{\alpha}} T = 0 \tag{27}$$

Here, all suppliers (the entrant and the incumbent) finance fund T with a proportional tax t related to the volume of electricity supplied so that: $T = \left(\overline{\alpha}\breve{q}^I_{\overline{\mu}} + \underline{\alpha}\breve{q}^K_{\underline{\mu}}\right) t$. This strong assumption is particularly relevant if the opportunity cost of public funding is near to zero. Substituting T in expression (27) yields:

$$a\breve{q}^{I}_{\overline{\mu}} - c_t(\breve{q}^{I}_{\overline{\mu}}, \overline{\mu}) + \frac{t}{\alpha}\left(\overline{\alpha}\breve{q}^{I}_{\overline{\mu}} + \underline{\alpha}\breve{q}^{K}_{\underline{\mu}}\right) = 0$$

Isolating tax t, leads to:

$$\begin{aligned} t &= \frac{\overline{\alpha}\left[c_t(\breve{q}^{I}_{\overline{\mu}}, \overline{\mu}) - \frac{\breve{q}^{I}_{\overline{\mu}}}{\breve{q}^{K}_{\underline{\mu}}}F(\underline{\mu})\right]}{\overline{\alpha}\breve{q}^{I}_{\overline{\mu}} + \underline{\alpha}\breve{q}^{K}_{\underline{\mu}}} \\ \Leftrightarrow \quad \breve{t} &= \frac{\breve{q}^{I}_{\overline{\mu}}}{\breve{q}^{I}_{\overline{\mu}} + \eta\breve{q}^{K}_{\underline{\mu}}}\left[\frac{F(\overline{\mu})}{\breve{q}^{I}_{\overline{\mu}}} - \frac{F(\underline{\mu})}{\breve{q}^{K}_{\underline{\mu}}}\right] \end{aligned} \tag{28}$$

Comparing expressions (21), (27) and (28) with $\widetilde{q}^{K}_{\underline{\mu}} = \breve{q}^{K}_{\underline{\mu}}$ yields:

$$\widetilde{a} = \breve{a} + \breve{t} \tag{29}$$

The introduction of a tax charged on the supply activity modifies the structure of the profit and supply functions of the firms. Note that from a simple static comparative argument, it can be show that unit tax $\breve{t}$ is higher (resp. lower) when the proportion of consumers with a high (resp. low) cost of connection increases.

4.1 Corporate profits and quantities supplied

Let us write the incumbent's net profit derived from the activity of electricity supply to the consumers of type $\mu = \underline{\mu}$ (if the incumbent serves these consumers), for a given tax:

$$\begin{aligned} \breve{\pi}_I(\breve{q}^{I}_{\underline{\mu}}, \underline{\mu}) &= \widehat{\pi}_I(\breve{q}^{I}_{\underline{\mu}}, \underline{\mu}) - \breve{t}\,\breve{q}^{I}_{\underline{\mu}} \\ &= T(\breve{q}^{I}_{\underline{\mu}}, \underline{\mu}) - \left(k + \breve{t}\right)\breve{q}^{I}_{\underline{\mu}} - c_t(\breve{q}^{I}_{\underline{\mu}}, \underline{\mu}) \end{aligned}$$

In that case, the quantity provided by the incumbent to consumers of type $\mu = \underline{\mu}$ is:

$$\begin{aligned} \breve{q}^{I}_{\underline{\mu}} &= \arg\max_{q \geq 0}\left\{\breve{\Pi}_I(q, \underline{\mu}) = \underline{\alpha}\breve{\pi}_I(q, \underline{\mu})\right\} \\ &\Leftrightarrow \; T'(\breve{q}^{I}_{\underline{\mu}}, \underline{\mu}) - k - \breve{t} - c = 0 \\ &\Leftrightarrow \; w'(\breve{q}^{I}_{\underline{\mu}}) = k + c + \breve{t} \end{aligned} \tag{30}$$

The direct comparison of this expression and (12) yields (with $\breve{t} > 0$):

$$\breve{q}^{I}_{\underline{\mu}} < q^{FB} \tag{31}$$

Now we compute the incumbent's net profit derived from the activity of electricity supply to consumers of type $\mu = \overline{\mu}$, for a given tax.

$$\begin{aligned}
\breve{\pi}_I(\breve{q}^I_{\overline{\mu}}, \overline{\mu}) &= \widehat{\pi}_I(\breve{q}^I_{\overline{\mu}}, \overline{\mu}) - \breve{t}\,\breve{q}^I_{\overline{\mu}} + \frac{1}{\overline{\alpha}}T \\
&= T(\breve{q}^I_{\overline{\mu}}, \overline{\mu}) - (k + \breve{t}\,)\breve{q}^I_{\overline{\mu}} - c_t(\breve{q}^I_{\overline{\mu}}, \overline{\mu}) + \frac{1}{\overline{\alpha}}T
\end{aligned}$$

The quantity supplied by the incumbent to consumers of type $\mu = \overline{\mu}$ is then:

$$\begin{aligned}
\breve{q}^I_{\overline{\mu}} &= \arg\max_{q \geq 0} \left\{ \breve{\Pi}_I(q, \overline{\mu}) = \overline{\alpha}\breve{\pi}_I(q, \overline{\mu}) \right\} \\
&\Leftrightarrow \; T'(\breve{q}^I_{\overline{\mu}}, \overline{\mu}) - k - \breve{t} - c = 0 \\
&\Leftrightarrow \; w'(\breve{q}^I_{\overline{\mu}}) = k + c + \breve{t} \Rightarrow \breve{q}^I_{\overline{\mu}} < q^{FB} \qquad (32)
\end{aligned}$$

Finally, we determine the entrant's net profit when providing electricity to consumers of type $\mu = \overline{\mu}$, for a given tax:

$$\breve{\pi}_E(\breve{q}^E_{\underline{\mu}}, \overline{\mu}) = T(\breve{q}^E_{\underline{\mu}}, \underline{\mu}) - (\breve{a} + k + \breve{t}\,)\breve{q}^E_{\underline{\mu}}$$

The optimal quantity supplied by the entrant is then:

$$\begin{aligned}
\breve{q}^E_{\underline{\mu}} &= \arg\max_{q \geq 0} \left\{ \breve{\Pi}_E(q, \underline{\mu}) = \underline{\alpha}\breve{\pi}_E(q, \underline{\mu}) \right\} \\
&\Leftrightarrow \; T'(\breve{q}^E_{\underline{\mu}}, \underline{\mu}) - \left(\breve{a} + k + \breve{t} \right) = 0 \\
&\Leftrightarrow \; w'(\breve{q}^E_{\underline{\mu}}) = \breve{a} + k + \breve{t} \qquad (33)
\end{aligned}$$

A glance at (29) shows that $\breve{q}^E_{\underline{\mu}} = \widetilde{q}^E_{\underline{\mu}}$

4.2 Surplus sharing between a consumer of type μ and firm K

The net surplus derived from the relationship between the consumers of type $\mu = \underline{\mu}$ and firm I is:

$$s(\breve{q}^I_{\underline{\mu}}, \underline{\mu}) = S(\breve{q}^I_{\underline{\mu}}, \underline{\mu}) - \breve{t}\,\breve{q}^I_{\underline{\mu}} \ll S(q^{FB}, \underline{\mu})$$

with $K = I$ in $\breve{t}$ (see 28).

The net surplus derived from the relationship between the consumers of type $\mu = \overline{\mu}$ and firm I is:

$$\begin{aligned}
s(\breve{q}^I_{\overline{\mu}}, \overline{\mu}) &= S(\breve{q}^I_{\overline{\mu}}, \overline{\mu}) - \breve{t}\,\breve{q}^I_{\overline{\mu}} + \frac{1}{\overline{\alpha}}T \\
&= S(\breve{q}^I_{\overline{\mu}}, \overline{\mu}) + \eta\,\breve{t}\,\breve{q}^K_{\underline{\mu}}
\end{aligned}$$

The net surplus derived from the relationship between the consumers of type $\mu = \underline{\mu}$ and firm E is:

$$s(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu}) = S(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu}) - \breve{t}\, q_{\underline{\mu}}^{E}$$

with $K = E$ in $\breve{t}$.

With respect to the previous regimes, the best reply function of firm E in response to the strategy u of firm I writes:

$$\underline{u}_E(u) = \begin{cases} u & \text{if } u < s(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu}) \\ \upsilon,\ \forall \upsilon \in \left[0, s(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu})\right[& \text{if } u \geq s(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu}) \end{cases}$$

4.3 The incumbent's strategy

4.3.1 The incumbent serves the two types of consumers

When the incumbent serves consumers of type $\mu = \underline{\mu}$, its total profit is (taking into account regulation rules and fund transfers):

$$\begin{aligned} \widehat{\Pi}_I^I &= \underline{\alpha}\breve{\pi}_I(\breve{q}_{\underline{\mu}}^{I}, \underline{\mu}) + \overline{\alpha}\breve{\pi}_I(\breve{q}_{\overline{\mu}}^{I}, \overline{\mu}) = \underline{\alpha}\left(s(\breve{q}_{\underline{\mu}}^{I}, \underline{\mu}) - u\right) + \overline{\alpha}\left(s(\breve{q}_{\overline{\mu}}^{I}, \overline{\mu}) - u\right) \\ &\Leftrightarrow\ \widehat{\Pi}_I^I = \breve{W}_{II} - u \end{aligned}$$

where $\breve{W}_{II} = \overline{\alpha}S(\breve{q}_{\overline{\mu}}^{I}, \overline{\mu}) + \underline{\alpha}S(\breve{q}_{\underline{\mu}}^{I}, \underline{\mu})$

As in the CS regime, the incumbent strategy $\breve{u} \in \arg\max_{u \geq s(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu})} \widehat{\Pi}_I^I$ is to offer to the consumers the minimum level of utility $u = \breve{u}_{II} = s(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu})$. In that case, the incumbent profit becomes:

$$\widehat{\Pi}_I^I = \breve{W}_{II} - s(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu}) \tag{34}$$

4.3.2 The entrant serves the profitable consumers

The entrant serves consumers of type $\mu = \underline{\mu}$ if $s(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu}) > u$; the total profit for the incumbent is then:

$$\begin{aligned} \widehat{\Pi}_I^E &= \underline{\alpha}\pi_t(\breve{q}_{\underline{\mu}}^{E}, \underline{\alpha}) + \overline{\alpha}\breve{\pi}_I(\breve{q}_{\overline{\mu}}^{I}, \overline{\mu}) = \overline{\alpha}\left(s(\breve{q}_{\overline{\mu}}^{I}, \overline{\mu}) - u\right) + \underline{\alpha}s(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu}) - \underline{\alpha}s(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu}) \\ &\Leftrightarrow\ \widehat{\Pi}_I^E = \breve{W}_{IE} - \overline{\alpha}u - \underline{\alpha}s(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu}) \end{aligned}$$

where $\breve{W}_{IE} = \overline{\alpha}S(\breve{q}_{\overline{\mu}}^{I}, \overline{\mu}) + \underline{\alpha}S(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu})$

In the same way as for the CS regime, this profit is maximized for $u = 0$; so the level of utility offered to the consumers is $\underline{u}_E(u) = \overline{u}_I = \breve{u}_{IE} = 0$. In that case:

$$\widehat{\Pi}_I^E = \breve{W}_{IE} - \underline{\alpha}s(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu}) \tag{35}$$

4.3.3 Comparison of profits

We compare the two levels of the incumbent's profit in order to point out the strategy chosen by the leader:

$$\Delta\widehat{\Pi} = \widehat{\Pi}_I^I - \widehat{\Pi}_I^E = \breve{W}_{II} - \breve{W}_{IE} - \overline{\alpha}s(\breve{q}_{\underline{\mu}}^E, \underline{\mu}) \tag{36}$$

In that case:

$$\Delta\widehat{\Pi} \gtreqless 0 \Leftrightarrow \breve{W}_{II} \gtreqless \breve{W}_{IE} + \overline{\alpha}s(\breve{q}_{\underline{\mu}}^E, \underline{\mu})$$

Lemma 2 *In the same way as for the CS regime, if social welfare $\breve{W}_{II}$ is relatively higher (resp. lower) than $\breve{W}_{IE}$, then it is profitable (resp. not profitable) for the incumbent to serve the consumers of type $\mu = \underline{\mu}$; in that case, the entrant is inactive (resp. active).*

When the level of utility $\breve{u}_{II} = s(\breve{q}_{\underline{\mu}}^E, \underline{\mu})$ given to the consumers is too high, then the incumbent would prefer not to serve the profitable consumers. In that case, the incumbent is inactive and the entrant offers a zero utility level; this regime is prejudicial to the consumers Consequently, we can prove[11] that the regime where the incumbent serves the consumers of type $\mu = \underline{\mu}$ is better from a collective point of view ($\breve{W}_{II} > \breve{W}_{IE}$).

5 Comparison of USO funding mechanisms: welfare analysis

In our paper, each regulatory mechanism of funding for USOs (through access charge or through taxation) implies two electricity market structures:

- First, it is profitable for the incumbent to serve the consumers of type $\mu = \underline{\mu}$ so that the entrant is inactive;
- Second, the incumbent has no incentive to serve the consumers of type $\mu = \underline{\mu}$ so that the entrant is active;

  We have to compare four alternative situations in terms of social welfare.

First it is useful to show that

$$s(\breve{q}_{\underline{\mu}}^E, \underline{\mu}) < S(\widetilde{q}_{\underline{\mu}}^E, \underline{\mu}) - \pi_t(\widetilde{q}_{\underline{\mu}}^E, \underline{\mu})$$

[11] Actually we show in appendix B that $\breve{q}_{\underline{\mu}}^E < \breve{q}_{\underline{\mu}}^I$ and this yields the result.

Indeed using (26), (29) and the previous result $\breve{q}^{E}_{\underline{\mu}} = \widetilde{q}^{E}_{\underline{\mu}}$, we have

$$\breve{t}\, q^{E}_{\underline{\mu}} - \pi_t(\widetilde{q}^{E}_{\underline{\mu}}, \underline{\mu}) = \left(\widetilde{a} + \breve{a}\right) \widetilde{q}^{E}_{\underline{\mu}} > 0 \tag{37}$$

This relation facilitates comparisons between the differences in incumbent's profit levels in the CS and T regimes.

SITUATION I.

If the incumbent serves the two types of consumers in the Taxation and Cross Subsidies regimes, then these two inequalities hold (see lemma 1 and 2):

$$\begin{cases} \breve{W}_{II} \geq \breve{W}_{IE} + \overline{\alpha} s(\breve{q}^{E}_{\underline{\mu}}, \underline{\mu}) \\ \widetilde{W}_{II} \geq \widetilde{W}_{IE} + \overline{\alpha}\left(S(\widetilde{q}^{E}_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^{E}_{\underline{\mu}}, \underline{\mu})\right) \end{cases}$$

So must compare welfare levels $\breve{W}_{II}$ and $\widetilde{W}_{II}$ in order to assess the best funding mechanism for USO. Using (31) and recalling that $\breve{q}^{I}_{\underline{\mu}} < q^{FB}$, yields:

$$S(\breve{q}^{I}_{\underline{\mu}}, \underline{\mu}) < S(q^{FB}, \underline{\mu}) \Rightarrow \breve{W}_{II} < \widetilde{W}_{II}$$

Proposition 1 *If the incumbent serves consumers of type $\mu = \underline{\mu}$, the funding for USOs through access charge is better in terms of social welfare.*

From an allocative efficiency point of view (without equity concerns), the access charge regime dominates the fund: this result simply stems from the distorsion caused by taxation.

SITUATION II

If I (resp. E) serves consumers of type $\mu = \underline{\mu}$ in the Taxation (resp. Cross Subsidies) regime, the following holds:

$$\begin{cases} \breve{W}_{II} \geq \breve{W}_{IE} + \overline{\alpha} s(\breve{q}^{E}_{\underline{\mu}}, \underline{\mu}) \\ \widetilde{W}_{II} \leq \widetilde{W}_{IE} + \overline{\alpha}\left(S(\widetilde{q}^{E}_{\underline{\mu}}, \underline{\mu}) - \pi_t(\widetilde{q}^{E}_{\underline{\mu}}, \underline{\mu})\right) \end{cases}$$

Now we must compare social welfare levels $\breve{W}_{II}$ and $\widetilde{W}_{IE}$. This is achieved through the comparison of the surplus derived from the relationship between firm K and consumers of type $\mu = \underline{\mu}$. In other words, we have to compare: $w'(\widetilde{q}^{E}_{\underline{\mu}}) = k + \widetilde{a}_{|K=E}$ and $w'(\breve{q}^{I}_{\underline{\mu}}) = k + c + \breve{t}_{|K=I}$, that is

$$\widetilde{a} = c + \frac{F(\overline{\mu}) + \eta F(\underline{\mu})}{\widetilde{q}^{I}_{\overline{\mu}} + \eta \widetilde{q}^{K}_{\underline{\mu}}} \quad \text{and} \quad c + \breve{t} = c + \frac{F(\overline{\mu}) - \frac{\breve{q}^{I}_{\overline{\mu}}}{\breve{q}^{K}_{\underline{\mu}}} F(\underline{\mu})}{\breve{q}^{I}_{\overline{\mu}} + \eta\, \breve{q}^{K}_{\underline{\mu}}}$$

In fact, it leads to compare $\frac{F(\overline{\mu})+\eta F(\underline{\mu})}{\widetilde{q}^I_{\overline{\mu}}+\eta\widetilde{q}^K_{\underline{\mu}}}$ and $\frac{F(\overline{\mu})-\frac{\breve{q}^I_{\overline{\mu}}}{\breve{q}^K_{\underline{\mu}}}F(\underline{\mu})}{\breve{q}^I_{\overline{\mu}}+\eta\breve{q}^K_{\underline{\mu}}}$ in order to classify the quantity of electricity supplied to consumers of type $\mu=\underline{\mu}$ in the two funding regimes. From appendix B, we obtain:

$$\widetilde{q}^E_{\underline{\mu}} < \breve{q}^I_{\underline{\mu}} \Rightarrow S(\widetilde{q}^E_{\underline{\mu}},\underline{\mu}) < S(\breve{q}^I_{\underline{\mu}},\underline{\mu})$$

Furthermore, we have known that $\breve{q}^I_{\overline{\mu}} < q^{FB}$ so

$$\widetilde{W}_{IE} \gtrless \breve{W}_{II}$$

Proposition 2 *If it is profitable for the incumbent (resp. the entrant) to serve the consumers of type $\mu=\underline{\mu}$ under the Taxation (resp. Cross Subsidies) regime, the funding regime for USOs through taxation can be welfare improving*

In that situation, the fund regime can be welfare improving. This case corresponds to a non-competitive *ex post* industrial structure, that is the incumbent serves all the consumers.

SITUATION III

I (resp. E) serves the consumers of type $\mu=\underline{\mu}$ in the Cross Subsidies (resp. Taxation) regime.

$$\begin{cases} \breve{W}_{II} \leq \breve{W}_{IE} + \overline{\alpha}s(\breve{q}^E_{\underline{\mu}},\underline{\mu}) \\ \widetilde{W}_{II} \geq \widetilde{W}_{IE} + \overline{\alpha}\left(S(\widetilde{q}^E_{\underline{\mu}},\underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}},\underline{\mu})\right) \end{cases}$$

Comparing $w'(\widetilde{q}^I_{\underline{\mu}}) = k+c$ and $w'(\breve{q}^E_{\underline{\mu}}) = k+\breve{a}+\breve{t}$ yields:

$$\begin{aligned} \widetilde{q}^I_{\underline{\mu}} &= q^{FB} > \breve{q}^E_{\underline{\mu}} \Rightarrow S(q^{FB},\underline{\mu}) > S(\breve{q}^E_{\underline{\mu}},\underline{\mu}) \\ &\Rightarrow \widetilde{W}_{II} > \breve{W}_{IE} \end{aligned} \tag{38}$$

Proposition 3 *If its profitable for the incumbent (resp. the entrant) to serve consumers of type $\mu=\underline{\mu}$ under the Cross Subsidies (resp. Taxation) regime, then the funding for USOs through access charge is better in terms of social welfare.*

As in the former situation 1, the fund is not welfare improving because of both the tax distorsions and the strategic behaviour of the imcumbent (it offers more surplus to all consumers in CS regime)

SITUATION IV

In the two funding regimes, the entrant serves the consumers of type $\mu=\underline{\mu}$.

$$\begin{cases} \breve{W}_{II} \leq \breve{W}_{IE} + \overline{\alpha}s(\breve{q}^E_{\underline{\mu}},\underline{\mu}) \\ \widetilde{W}_{II} \leq \widetilde{W}_{IE} + \overline{\alpha}\left(S(\widetilde{q}^E_{\underline{\mu}},\underline{\mu}) - \pi_t(\widetilde{q}^E_{\underline{\mu}},\underline{\mu})\right) \end{cases}$$

Comparing $w'(\widetilde{q}_{\underline{\mu}}^{E}) = k + \widetilde{a}$ and $w'(\breve{q}_{\underline{\mu}}^{E}) = k + \breve{a} + \breve{t}$ yields:

$$\begin{aligned} \widetilde{q}_{\underline{\mu}}^{E} &= \breve{q}_{\underline{\mu}}^{E} \Rightarrow S(\widetilde{q}_{\underline{\mu}}^{E}, \underline{\mu}) = S(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu}) \\ &\Rightarrow \widetilde{W}_{IE} > \breve{W}_{IE} \end{aligned} \tag{39}$$

Proposition 4 *If the entrant serves the consumers of type $\mu = \underline{\mu}$ (through access charge or through taxation) then the funding for USOs through access charge is better in terms of social welfare.*

The following table I sum up all previous results.

	I serves profitable consumers CROSS SUBSIDIES REGIME	E serves profitable consumers CROSS SUBSIDIES REGIME
I serves profitable consumers FUND REGIME	$\widetilde{W}_{II} > \breve{W}_{II}$ Access Charge	$\widetilde{W}_{IE} \gtrless \breve{W}_{II}$ Fund or Access Charge
E serves profitable consumers FUND REGIME	$\widetilde{W}_{II} > \breve{W}_{IE}$ Access Charge	$\widetilde{W}_{IE} > \breve{W}_{IE}$ Access Charge

Table I : Welfare analysis results

Whatever the profitability of the firms, the cross-subsidies regime is better off in terms of welfare. This is due to distortion effects of the taxation. Nevertheless, in the case where entry is profitable under the cross-subsidies regime and non profitable under the taxation regime, the USO fund could be dominant in terms of welfare but entry will be effectively prevented. In fact there is no case where entry and taxation regime of funding are simultaneously realized.

If we select the welfare improving funding mechanisms in the four previous situations (see. table I), we can further analyze the utility levels given to the consumers:

	I serves in CS regime	E serves in CS regime
I serves in T regime	$\widetilde{u}_{II}$	$\breve{u}_{II}$ / $\widetilde{u}_{IE} = 0$
E serves in T regime	$\widetilde{u}_{II}$	$\widetilde{u}_{IE} = 0$

Table II : Equilibrium utility levels where $\widetilde{u}_{II} = S(\widetilde{q}_{\underline{\mu}}^{E}, \underline{\mu}) - \pi_t(\widetilde{q}_{\underline{\mu}}^{E}, \underline{\mu})$ and $\breve{u}_{II} = S(\breve{q}_{\underline{\mu}}^{E}, \underline{\mu}) - \breve{t}\,\breve{q}_{\underline{\mu}}^{E}$

Using (37), we can easily compare $\widetilde{u}_{II}$ and $\breve{u}_{II}$:

$$\widetilde{u}_{II} > \breve{u}_{II} > \widetilde{u}_{IE} = \breve{u}_{IE} = 0$$

When the incumbent serves the profitable consumers, it's interesting to see that the mechanism of funding for USOs is not neutral in terms of utility level left to the consumers. The superiority of the CS regime doesn't stem from a higher level profit for the incumbent. If the incumbent serves the consumers of type $\mu = \underline{\mu}$, it is profitable for the collectivity (and specially for the consumers) to fund the USOs through access charge. As a result, the level of utility given to the consumers is higher when the incumbent serves the profitable consumers.

6 Conclusion

In this paper, we have analyzed two mechanisms of funding for USOs in the special case of the electricity sector. Using a competitive network model, we obtain some results concerning gains and losses of social welfare due to those mechanisms. We comment these results which are summarized in tables I and II.

Whatever the type of funding for USOs applying, and whatever profitability of the firms, the following inequality chain holds: $\widetilde{W}_{II} > \breve{W}_{II} \gtrless \widetilde{W}_{IE} > \breve{W}_{IE}$. This means that most of the time it is socially better to let the incumbent be active (if it is profitable for him). This result is obvious since the level of access charge (fixed under a " cost of service regulation") is different from transport marginal cost which is the effective transfer price of the vertically integrated incumbent. Another reason for this result stems from the position of the incumbent which is the leader of the sequential game. Analysing previous inequality, we conclude that the funding through access charge is better when the incumbent serves the profitable consumers: in that case, the introduction of taxation induces welfare distortions coming from fall of the incumbent profit. Nevertheless, the two cases where entry is effective and welfare improving are supported by an access policy.

Contrarily, when the entrant is active under access charge regime, we can highlight that the introduction of the taxation regime implies either welfare deterioration or an entry deterrence strategy by the historical firm. Therefore, the taxation regime could not be an argument for the regulator to promote vertical separation of the historical firm (according to the European community line). There is a conflict between the access policy and the funding for USO through taxation.

Our model could be extended for further research in the framework of funding for USOs in the electricity market:

First, it could be possible to implement other types of taxation regimes. For instance, we could develop the case where the tax is only imposed on profitable consumers. Unfortunately, this case generates similar results in terms of social welfare. Another possibility could be to charge the transport activity (instead of distribution activity) for the incumbent. Finally, in a normative perspective, it could be interesting to determine the levels of access charge and tax which entail maximum social welfare. Nevertheless, one can intuitively think that these optimal levels will be the same because of increasing returns to scale in the transport activity.

Second, following the European community line, it could very interesting to extend the incumbent accounting separation to a totally vertically separated firm. Such a separation could entail a social optimal entry (a more competitive electricity market) under a taxation regime.

Third, a crucial assumption of our paper is that firms are able to practice perfect price discrimination; this gives a significant initial advantage to the incumbent. In Madet *et al.* (2003), it can be shown that, compared to non-linear pricing, the requirement of uniform prices will reduce this market power of the incumbent. As a result, it is possible to show that funding regime is not always dominated.

Fourth, an important issue arises concerning the informational context in this model. Actually, we did not initially integrate informational asymmetries between the regulator and the operator in charge of USOs. This is a relevant question in the context of the transparency of accounts where it is particularly difficult for the regulator to know exactly the fixed cost sharing between the two types of consumers. It would be advantageous to introduce incentive contracts for USOs between the regulator and the incumbent.

Finally, a restrictive assumption is made in our model concerning the Restricted Entry regime: the entrant is not authorized to supply electricity to non profitable consumers. This assumption stems from the European framework where the historical monopolies are in charge with the Universal Service Obligations. We can now mention the possibilities of allocation for USOs to extend the " restricted entry" scenario:

1. The pay or play rule[12] (Chone *et alii.* 2002) could be a regulatory mechanism to allocate the Universal Service Obligations. Under such a regulatory rule, " the entrant may choose to serve the non profitable users instead of paying a tax" . In other words, when the incumbent serves the non profitable consumers, the entrant has to pay a tax corresponding to its funding share for USOs. On the contrary, if the entrant serves the non profitable

[12] The pay or play regulation is applied in Australia.

consumers, it is exempted from this tax.

2. Regulators could use second price auctions to allocate the USOs (e.g. see Anton J. *et alii* 1999). As written in Chone *et alii* (2002), " *in such a mechanism, the ubiquity constraint may be sold to the competitors through an auction mechanism. Each competitor bid for a subsidy for serving the* $\mu = \underline{\mu}$ *consumers. The firm that requires the lowest subsidy wins the auctions (i.e. serves the market). Assume that this auction mechanism is financed through transfers. Then the government transfers to the winning firm the value required by the other firm to serve the high cost consumers*[13]" .

3. Finally, as it has been made for the allocation of UMTS telecom frequencies in France, USOs could be allocated on the basis of an attribution after examinations (so called " beauty contest" procedure).

7 Appendices

7.1 Appendix A: optimal access charge in the benchmark case

If we override the assumption of a cost of service regulation, an optimal access charge can be determined by a risk neutral regulator with a social welfare objective. Choosing a level of access charge, the regulator wants to maximize the social surplus (of the $\underline{\mu}$ consumers) knowing the firm's reply in the downstream industrial game (see benchmark case above). So the program of the regulator is given by:

$$\begin{cases} \max\limits_{a \in \mathsf{R}_+} \max \left\{ \underline{\alpha} S\left(q^E_{\underline{\mu}}(a),\right), \underline{\alpha} S\left(q^I_{\underline{\mu}}(a),\right) \right\} \\ q^I_{\underline{\mu}}(a) \in \arg\max\limits_{q \in \mathsf{R}_+} \widehat{\pi}_I(q, \underline{\mu}) \\ q^E_{\underline{\mu}}(a) \in \arg\max\limits_{q \in \mathsf{R}_+} \pi_E(q, \underline{\mu}) \end{cases}$$

The solution of the downstream industrial sequential game is now dependent on a; however relations (14) and (15) in the text hold on. Hence an active incumbent will produce again at the first-best level but its profits will be determined by:

$$\hat{\pi}_I(q^{FB}, \underline{\mu}) = S(q^{FB}, \underline{\mu}) - \underline{u}_I = S(q^{FB}, \underline{\mu}) - \left[S(q^E_{\underline{\mu}}(a), \underline{\mu}) - \pi_t(q^E_{\underline{\mu}}(a), \underline{\mu}) \right] \geq 0$$

Actually the incumbent transport account is not necessarily zero, especially without "cost of service" regulation. On the other hand, if the entrant is active, the following relations hold (entrant profitable, incumbent not):

$$\begin{cases} \pi_E(q^E_{\underline{\mu}}(a), \underline{\mu}) = S(q^E_{\underline{\mu}}(a), \underline{\mu}) - \underline{u}_E(\underline{u}_I) - \pi_t(q^E_{\underline{\mu}}(a), \underline{\mu}) \geq 0 \\ \hat{\pi}_I(q^{FB}, \underline{\mu}) < 0 \end{cases}$$

[13] As it is well known in literature on auctions, the second-price auctions (Vickrey) allow for the firm to reveal information about its real " willingness to pay" for serving the non profitable users.

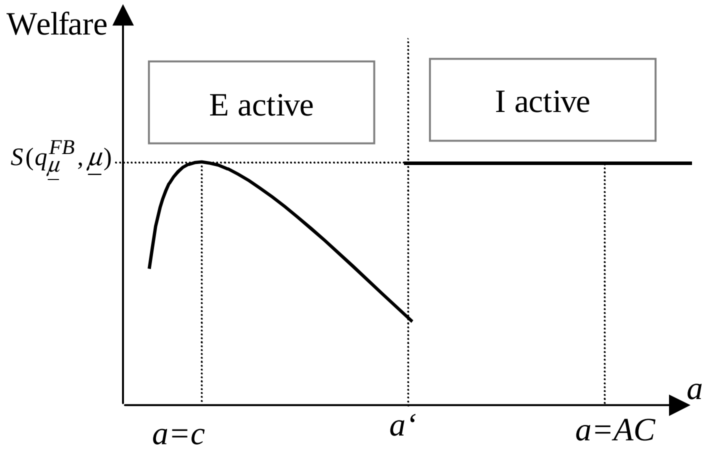

Figure 2: *Per capita* welfare profile

Let a' the access charge level such that when $a = a'$:

$$\begin{aligned}
\hat{\pi}_I(q^{FB}, \underline{\mu}) &= 0 \Leftrightarrow S(q^E_{\underline{\mu}}(a), \underline{\mu}) - \pi_t(q^E_{\underline{\mu}}(a), \underline{\mu}) = S(q^{FB}, \underline{\mu}) \\
&\Leftrightarrow \underbrace{w(q^E_{\underline{\mu}}(a), \underline{\mu}) - (k+a)\, q^E_{\underline{\mu}}(a)}_{\phi(a)} = S(q^{FB}, \underline{\mu})
\end{aligned}$$

Using envelop theorem, we see that $\phi(a)$ is an decreasing function of a ($\phi'(a) = -q^E_{\underline{\mu}}(a)a < 0$). Furthermore it is easy to check that:

- $\phi(c) > S(q^{FB}, \underline{\mu})$ because $q^E_{\underline{\mu}}(c) = q^{FB}$so $\phi(c) - S(q^{FB}, \underline{\mu}) = \frac{F(\underline{\mu})}{q^{FB}} > 0$
- and $\phi\left(F(\underline{\mu})/q^E_{\underline{\mu}}\right) < S(q^{FB}, \underline{\mu})$ because the relation (17) in the text holds here. So a' does exist; it is then a threshold such that if $a < a'$ only firm E is active and *per capita* welfare is given by $S(q^E_{\underline{\mu}}(a), \underline{\mu}) \leq S(q^{FB}, \underline{\mu})$. If $a \geq a'$ only firm I is active and *per capita* welfare is constant and equal to $S(q^{FB}, \underline{\mu})$. The following figure shows the welfare as a function of the access charge.

The regulator's problem is now solved, there is a set of optimal access charges including the "cost-of service" one, formally $S_a = \{c\} \cup [a', +\infty[$.

7.2 Appendix B: production level comparison for the " Fund" case

We have to compare $\breve{q}^I_{\underline{\mu}}$ and $\breve{q}^E_{\underline{\mu}}$. Using (30) and (33), we derive the following system:

$$\begin{cases} w'\left(\breve{q}^I_{\underline{\mu}}\right) = k + c + \breve{t} \\ w'\left(\breve{q}^E_{\underline{\mu}}\right) = k + \breve{a} + \breve{t} \end{cases}$$

Using (26), (28) and (32) for manipulations leads to:

$$\begin{cases} w'\left(\breve{q}^{I}_{\underline{\mu}}\right) - (k+c) = \frac{1}{\breve{q}^{I}_{\overline{\mu}} + \eta \breve{q}^{I}_{\underline{\mu}}} \left(F(\overline{\mu}) - F(\underline{\mu}) \frac{\breve{q}^{I}_{\overline{\mu}}}{\breve{q}^{I}_{\underline{\mu}}}\right) \\ w'\left(\breve{q}^{E}_{\underline{\mu}}\right) - (k+c) = \frac{1}{\breve{q}^{I}_{\overline{\mu}} + \eta \breve{q}^{E}_{\underline{\mu}}} \left(F(\underline{\mu}) + \eta F(\overline{\mu})\right) \end{cases}$$

$$\Leftrightarrow \quad \begin{cases} \left(w'\left(\breve{q}^{I}_{\underline{\mu}}\right) - k - c\right)\left(\breve{q}^{I}_{\overline{\mu}} + \eta \breve{q}^{I}_{\underline{\mu}}\right) = F(\overline{\mu}) - F(\underline{\mu}) \frac{\breve{q}^{I}_{\overline{\mu}}}{\breve{q}^{I}_{\underline{\mu}}} \\ \left(w'\left(\breve{q}^{E}_{\underline{\mu}}\right) - k - c\right)\left(\breve{q}^{I}_{\overline{\mu}} + \eta \breve{q}^{E}_{\underline{\mu}}\right) = F(\underline{\mu}) + \eta F(\overline{\mu}) \end{cases}$$

$$\Gamma(q) \equiv \left(w'(q) - k - c\right)\left(\breve{q}^{I}_{\overline{\mu}} + \eta q\right) = \begin{cases} \gamma_I(q) \equiv F(\overline{\mu}) - F(\underline{\mu}) \frac{\breve{q}^{I}_{\overline{\mu}}}{q} & \text{if } K = I \\ \gamma_E(q) \equiv F(\underline{\mu}) + \eta F(\overline{\mu}) & \text{if } K = E \end{cases} \tag{B.1}$$

We analyze first the LHS of (B.1). $\Gamma'(q) = w''(q)\left(\breve{q}^{I}_{\overline{\mu}} + \eta q\right) + \eta\left(w'(q) - k - c\right)$ has an ambiguous sign, but using (12) we see that $\Gamma'(q^{FB}) = w''\left(q^{FB}\right)\left(\breve{q}^{I}_{\overline{\mu}} + \eta q^{FB}\right) < 0$. Moreover $\Gamma(q^{FB}) = 0$. So function Γ is locally decreasing in q for $q = q^{FB}$ then we can assume it is the case for some $q^K < q^{FB}$.

Second we show that $\gamma_E(q) > \gamma_I(q)$, $\forall q < q^{FB}$. Indeed,

$$\gamma_E(q^{FB}) = F(\underline{\mu}) + \eta F(\overline{\mu}) > \gamma_I(q^{FB}) = F(\overline{\mu}) - F(\underline{\mu}) \frac{\breve{q}^{I}_{\overline{\mu}}}{q^{FB}}$$

and $\gamma'_E(q^K) = 0, \gamma'_I(q^K) = \frac{\breve{q}^{I}_{\overline{\mu}}}{q^2} F(\underline{\mu}) > 0$, $\forall q^K < q^{FB}$ so $\gamma_E(q) > \gamma_I(q)$, $\forall q < q^{FB}$. Hence if $\Gamma(q)$ is decreasing in q for $q < q^{FB}$, then $\breve{q}^{I}_{\underline{\mu}} > \breve{q}^{E}_{\underline{\mu}}$.

References

[1] Armstrong M., C. Doyle and J. Vickers, 1996, The Access Pricing Problem: a synthesis", *Journal of Industrial Economics* 44(2), 131-150.

[2] Armstrong M., 2001, Access pricing, Bypass and Universal Service, *American Economic Review* 91, 297-301

[3] Anton J., J. Vander Weide and N. Vettas, 1999, Strategic Pricing and Entry under Universal Service and Cross-Market Price Constraints. *CEPR Discussion paper* 1 922.

[4] Cremer H., F. Gasmi, A. Grimaud and J.J. Laffont, 2001, Universal Service: an Economic Perspective Overview, *Annals of Public and Cooperative Economics* 72:1.

[5] Chone P., L. Flochel and A. Perrot, 1999, Allocating and funding Universal Service Obligations in a competitive network market, *Working Paper* N ° 9955, CREST, University of Paris I, Dpt of Economics, France.

[6] Chone P., L. Flochel and A. Perrot, 2000, Universal service obligations and competition, *Information Economics and Policy* 12, 249–259.

[7] Chone P., L. Flochel and A. Perrot, 2002, Allocating and funding universal service obligations in a competitive market, *International Journal of Industrial Organization* 20, 1247–1276.

[8] David L. and F. Mirabel, 2000, Structure du marché gazier américain, réglementation et tarification de l'accès des tiers au réseau, *Working Paper* N° 00.06.17, CREDEN, University of Montpellier I, Dpt of Economics, France.

[9] Hoernig S., 2001, Universal Service Obligations: Should they be imposed on entrants? *Working Paper*, Universidade Nova de Lisboa,

[10] Jehiel P. and B. Moldovanu B., 2000a, Licence Auctions and Market Structure, *Working Paper*, Universität Mannheim, July 2, 2000.

[11] Jehiel P. and B. Moldovanu, 2000b, Auctions with Downstream Interaction among Buyers, *RAND Journal of Economics* 31 768-791.

[12] Madet C., F. Mirabel, J.-C. Poudou and M. Roland, 2003, Funding Universal Service Obligations with an Essential Facility: Access Charge Uplift vs. Dedicated Fund, *Working Paper*, LASER-CREDEN, University of Montpellier 1, France.

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